PRESIDENT'S ADDRESS.

ADDRESS OF P. ALEX. PETERSON, PRESIDENT CANADIAN SOCIETY CIVIL ENGINEERS, ON LEAVING THE CHAIR AT CLOSE OF ANNUAL MEETING, JANUARY 25th, 1895.

One of the duties of the position to which the Society, a year ago, elected me, is the delivery of an address at the close of my term of office. It has been customary for the Presidents of sister Societies to give a general review of the professional progress and scientific advancement in subjects which allude to our profession, but sometimes a President has chosen a subject which he assumed would be of interest to the members of the Society, and at the same time a record of the progress of some great work, which he considered he was in some special degree qualified to speak of; so instead of giving a general sketch of professional progress during the past year, I have decided to give a review of what the Canadian Pacific Railway Company has done since 1886, in the way of re-construction.

You are all aware that the Canadian Pacific Railway Company took a contract from the Government on 21st Oct., 1880, to complete the Railway to the Pacific Coast in ten years, and that the work was pushed on with such energy that trains passed from tide water to tide water in November, 1885. In carrying out this work through an almost inaccessible wilderness, it was decided to construct a large amount of temporary work, which would carry the traffic safely for some years, and at the same time be of material use in the economical construction of the permanent works. This method of carrying out the work enabled the Company to open the line five years earlier than it could otherwise have done; it saved a large amount of money in first cost and in interest, it will save a large sum in ultimate cost, and it enabled the Company to earn $20,000,000 in the year fixed for the completion of the contract.

The temporary work put in the roadbed consisted principally of long and high wooden trestles to cross large ravines, small pile trestles to cross small streams, and wooden bridges with the substructure of piles or wooden cribs, and super-structure of wooden trusses with spans varying from 30 feet to 180 feet in length to cross important streams and large rivers.

FILLING TRESTLES.

On the Eastern Division between Cartier and Nepigon, and on the Western Division between Fort William and Winnipeg, where square timber could not readily be obtained, round timber cut in the nearest valley along the line was used, and the work was of a more temporary character than where good timber was obtainable, consequently the work of replacing it was commenced at an early date, and this was especially the case when the structures were long and high and required two or three years to fill. The Big Pic trestle on the Eastern Division 800 miles west of Montreal, which was 1300 feet in length and 70 feet high at the western end, and required nearly three seasons to fill, contained 172,123 yards. To have filled this trestle would have taken five seasons, if done by the ordinary hand dump car method, and would have cost not less than $94,668, whereas the work only cost $36,770, or 16¼ cents per cubic yard, leaving out the cost of the trestle, a saving on that trestle alone of $57,898, besides allowing the line to be opened five years earlier. On this same Division another large trestle, No. 799, 800 miles west of Montreal, was commenced in 1890 and finished in 1893, requiring 100,000 cubic yards. This was filled at a cost of $15,000, or 15 cents per cubic yard. At the time of construction it could have been filled only by borrowing rock at a cost of $159,600, or $2.85 per cubic yard. There have been filled on this Division 535 trestles, having a length of 86,138 ft., and requiring 4,095,612 yards of material to fill them, on which, not counting interest saved on capital, there has been saved to the Company at least one dollar per cubic yard, or $4,095,612, by putting in temporary structures and making banks by train with gravel and sand instead, or rock, or even earth from long haul cuts by horse cars.

Where trestles have been built over good solid ground or rock, not under water, the filling has been easily done; but in some places, with bad foundations, this filling has been attended with serious difficulties, and in certain cases on the Government sections, the risk of stopping traffic was so great that it was considered advisable to change the location of the line. In many instances a certain amount of risk had to be run, and was provided against in the way of having timber on hand ready to repair the track, so as to avoid an interruption to the traffic; and so successfully has this been done, that in no case has traffic been interrupted for more than a few hours at any one time. In one case at structure No. 740 on the north shore of Lake Superior 820 miles

west of Montreal, a trestle 8C0 feet long and 40 feet high had a culvert built under it, and was nearly filed when the central portion dropped down about 14 feet, carrying the centre of the culvert down, and leaving the outer portion of the slopes and the ends of the culvert in position. This culvert and embankment were built on a coarse gravel foundation, under which there must have been a hollow space, below the depth to which the piles had been driven, covered with a crust that was thick enough to carry the trestle and its load, but not strong enough to support the gravel bank.

On the Western Division between Fort William and Winnipeg, in a great number of places the trestles were built through lakes, the water being of various depths over soft black peaty material, often from fifty to seventy feet deep on a bed of sloping rock. In other cases the same character of bottom would be found, but without the sloping rock. In the case of the sloping rock when the trestle was nearly filled, the whole bank has slipped bodily down the slope into the lake. In other cases when the material was nearly up to the level of the track, and before the banks had run out to the proper slope, the lower portion would slide out, carrying with it the full width of the made bank at the top, see Plate IV, the bank sometimes carrying with it a great part of the trestle, and always very much distorting the alignment, so that new piles had to be driven or put in place in order to maintain the traffic. Another form of trestle that was met with was when deep lakes had to be crossed, where, from the nature of the rock on which the trestle stood, it would be dangerous to run the risk of the filling sliding down a steep slope, and carrying the trestle with it. Here there was nothing to do but divert the track, and in some instances it was found that a better and cheaper line was close at hand, which avoided the fill altogether. In other cases it seemed that the deepest portion of the lake had been chosen, and that by judicious change of location enough rock could be obtained on a better line to fill the shallower crossing of the lake. In other places the Government had put quantities of cross-logging, where there was no possibility of the logging supporting the bank that was to go in, and when earth was put upon it, the logs would sink in the centre, and cause the ends to bend upwards, and so allow the bottom to assume a curved form, which would slide down on the sloping rock. A great deal of expense had been gone to by the Government in putting in cross-logging under banks as much as fifty feet high, with soft bottoms through which it would settle, some of which the Company removed before attempting to

make the embankment. In such cases cross-logging is worse than useless, as it cannot support the bank, and sinks at the centre, allowing the outer ends to turn up, so as to form a blunt edge as it were, which pushes out the soft material underneath to each side.

Cross-logging is only of use when a low bank is to be carried on top of soft material, which is not quite able to sustain the load. Then the cross-logging will broaden the base and furnish a lighter material to reach the desired height; but when the bottom is so soft that the bank will go through it to a solid bottom, then the cross-logging is a serious disadvantage to the work, as it increases the tendency of the bank to slide out sideways. In some cases where the risks of filling were so many, and the danger of interruption to the traffic so serious, there being no chance to put in a temporary track without great delay, diversions were made. In all such cases shallower crossings were found, and the rock from the excavation made the fills. Of course the cost was greater than if a proper location had been made at first, but a good line has now been obtained, and one from which no further trouble or expense can arise. A little more care in locating the original line would have avoided the necessity for these changes. This emphasizes the necessity for greater care in the location of railways. No class of Engineering is more neglected than location. Any Engineer who can run a transit is often thought good enough to locate a line; but after the line is built, the mistakes are found, bad bottoms as just described are discovered, and sharp curves and steep grades are put in the line that might easily have been avoided, and, as a consequence, either the line has to be worked at heavy expense, or large sums of money have to be expended to build the line over, so that greater loads can be hauled and the line more economically worked.

The filling of some of the trestles on the section between Fort William and Winnipeg required the utmost care and the strictest supervision so as to avoid any serious interruption to the traffic. At trestle No. 226A, east of Barclay Station, 1,248 miles west of Montreal, sawdust was satisfactorily used for filling under the following circumstances. A pile trestle 335 ft. long and 8 ft. in height across a soft spot in a swamp between two clay hills required filling, and had the bottom been able to hold up the bank, only 2,880 cubic yards would have been required to make the embankment. Soundings were taken through black muck and soft clay for 60 feet without finding a hard bottom. Filling was commenced on the 30th July, 1891, and when 864 cars or 6,912 cubic yards had been put in, the track dropped on the

8th August about four feet over the whole length of the trestle. The track was raised and the filling was carried on till the 31st October, at which date 6,825 car loads had been put in, equal to 54,600 cubic yards, or 51,720 cubic yards more than was required to fill from the surface to subgrade. By this time the banks at both ends of the trestle had broken through, or rather had been carried down by the settlement that took place under the trestle, and the filling sank faster than it could be put in. The track was then below grade for a distance of eight hundred feet, and eleven feet below subgrade at the lowest place. This settlement took place by sudden drops of from six to seven feet, but was kept passable by cutting down the track on each side of the lowest point;—as the bank never fell more than 11 ft. below grade, which was the level of the water in the marsh;—and by filling in with sawdust, so as to enable the heavy wheat traffic to be carried over without assistance from a pusher. The track was raised to within six feet of grade, and the approaches cut down so as to make two per cent. grades, over which the ordinary traffic passed without difficulty. During the winter the sawdust filling gave no trouble, so in the spring it was decided to complete the bank to within a foot of the required height, and to cover it with a foot of gravel. The sawdust proved so satisfactory that it was decided to raise it three feet higher than the original trestle, in order to improve the grade at this point, which is near the east end of Barclay siding. The bank as filled has not shown any appreciable settlement and has remained in perfect order.

Bridge No. 169, 1,250 miles from Montreal, was a pile trestle 596 feet in length and nine feet high, built across a swamp, where soundings, or rather borings, were taken for sixty feet in depth without finding hard bottom. Previous experience in similar places showed that great expense would be entailed in attempting to fill this place with gravel, and that serious interruptions to traffic might be expected. Sawdust having been used with success on No. 226A above mentioned, it was decided to try filling this trestle altogether with sawdust, and to spread the weight out as much as possible by using flat slopes of 3 to 1. The sawdust was brought from Keewatin in box cars, containing 45 cubic yards, by freight trains each day, as the cars were filled by shoots leading from the mills and left on siding near by to be dumped by specia work gang sent out when siding was filled. The time required to fill the trestle was about three months. The sawdust was covered with a foot of ballast, and has remained in perfect condition, except 75 feet of the track, which required lifting and tamping for the first three monthe

probably due to the fact that the sawdust was thrown in loosely and not packed as at No. 226A. It has since shewn no signs of settlement and has given good satisfaction. The quantity of sawdust used was very little in excess of the quantity calculated from the cross section, showing that sawdust shrinks less than earth for a bank of the same dimensions, and it may be interesting to know that the sawdust bank yields less under a passing train than the trestle, and has less spring in it than a muck bank built over a swamp of the same character.

Trestle No. 177 across a bay of Eagle Lake was 634 feet in length and 23 feet above the surface of the water, built with frame bents on piles which were driven through very soft mud and clay overlying rock at depth varying from 20 feet to 40 feet. The rock sloped to the north at the west end and to the south at the east. A thick mattress of logs was, in the original construction by the Government, put in between the piles, or the piles were driven between them for the purpose of assisting to support the bank and to stiffen the piles, standing as they were in such very soft mud. Fearing that the mattress, which extended about fifty feet on each side of the trestle, in settling at the centre and turning up at the ends, would slide on the bottom and so wreck the trestle, it was decided to cut, from the ice during the winter, the mattress just outside the piles, as the simplest method of avoiding the danger likely to arise from the presence of the cross logging, on such a very soft bottom. Filling was commenced on 8th August, 1892, was carried on up to the 27th of the same month, up to which time 1,284 car loads had been put in, nearly all of which had been hauled by horses and scrapers to the edge of the cross logging left between the piles, and dumped over the ends of it so as to form two banks, or walls, outside of the trestle, and to make as much as possible of the bank, with the least interference with the trestle. In spite of this precaution the trestle sank two feet on the last mentioned date, and went out to the south about four feet, and continued sinking and going out of line steadily till, on the 29th September, when 4,674 cars or 37,392 cubic yards had been put in and hauled out by horses and scrapers, the bridge had settled 18 feet and was 12 feet out of line. It had been kept passable all this time by blocking up over the caps, as shown on Plan No. IV. Piles were then driven to the northward on the old line and the track placed in its original position. Filling was commenced again on the 3rd October, and continued to the 23rd, at which date 7,291 cars had been put in, and the new piles were as much out of line and had sunk as much as the old bridge had on the 29th September, and had of course during this time to be kept blocked up to keep the bridge open for the

heavy wheat traffic. Filling was now stopped for the season, and new piles were again driven and the track moved over into line. What remained of the old bridge was now 38 feet out of line. During the winter and up to the 2nd May, no more than two feet of settlement took place. Filling was recommenced on the 2nd May, and by the 9th May, 866 cars had been put in, when at 5 p.m. the bridge sank an average of 8 feet over 28 bents. At 1 p.m. on May 10th the track was passable and passenger train No. 2 crossed on time. On 10th and 11th of May, 305 cars were put in, and at 6 p.m. on the 11th the bridge sank an average of 8 feet over 18 bents, and though it rained heavily all night the track was passable at 9 a.m. the next morning.

On May 16th, when 371 more cars had been put in, the trestle again sank about 8 ft. over the same 18 bents, and went out of line 10 ft. to the south; but the track was blocked up, and made passable by one o'clock on the morning of the 17th, and all trains passed on time. Between May 17th and 20th, 544 more cars, or 4,352 cubic yds., were put in, when the trestle sank again about 8 ft. over the same 18 bents at one o'clock p.m.; track was, however, passable at 8 p.m. on the same day.

At 5 p.m. on May 23rd, when 442 more cars, or 3,536 cubic yds., had been put in, the trestle sank about 7 ft. over the same 18 bents, and went out 10 ft. to the south; but by 11 p.m. on the same day it was ready to pass trains, requiring something less than one hour to raise it each foot over the 240 ft. Three hundred and seventy-four more cars had been put in up to 5 p.m. of the 25th of May, when the trestle sank for the sixth time seven feet over the same 18 bents, causing a stoppage of the line at this point for seven hours. On 27th May, after 284 more cars, or 2,272 cubic yds., had been put in, this bank was within six feet of the grade, and by cutting down the approaches it was possible to lay the track on the filling. This was done and the filling stopped, so as to allow the bank to set and solidify. Work commenced again on the 21st of August, and between that date and the 9th of September, 788 cars were unloaded in small quantities at a time, and the bank brought up to grade 18 ft. wide at base of rail.

Between 9th September, 1893, and 31st July, 1894, the embankment settled about 2½ ft. at the lowest point. On the latter date 96 cars were unloaded, which brought the track up to grade and bank 16 ft. wide at base of rail. Since that date no appreciable settlement has taken place.

The filling of the trestle has been given in considerable detail in order to give a clear idea of the difficulties that are encountered in filling on

a bad bottom and sloping foundation, and to show what can be done in the way of keeping such a structure passable in the face of such difficulties, caused by the sudden sliding out into the lake of the original bottom of clay and mud overlying the hard bottom, and carrying with it the filling which rested upon it. The track sank in the autumn of 1892, 40 ft., and in May, 1893, 52 ft., besides smaller settlements that were going on all the time, and yet traffic was maintained, the greatest detention to any passenger train being eight hours, when the track sank at 6 p m. during a heavy rain, and was ready to pass the train at 9 a.m. next morning.

The estimated quantity of filling required for the trestle was 100,000 cubic yds. The total quantity put in was 96,000 yds., which cost $41,637.00.

When the foundations are good, the filling of a large trestle is attended with little or no risk. Settlements of trestles on apparently good foundations, however, occur, which it is difficult to account for, such as that at Big Pic, where, after the trestle had been filled some time, the bank and trestle subsided six feet in one night, and, as far as could be seen, no disturbance of the surrounding ground took place, nor has any further settlement taken place in the past five years.

Between Winnipeg and Donald, a distance of 1,024 miles, there are not many large trestles; a few of the large ones west of the summit of the Rockies have been filled, the policy adopted being to fill long, shallow ones, and so to reduce the length of wooden floors as much as possible with the least amount of money, except in certain cases where transfers could not be made or diversions readily built. West of the Summit most of the trestles filled were situated on sides of hills, and required retaining walls to hold the banks and prevent the slopes from running down into the Kicking Horse River.

From Savonas to Port Moody, a distance of 213 miles, built by the Government, a large amount of work has been done, 27,746 ft. of trestles having been filled. In all cases the streams are carried through the banks in stone arches or box culverts, and where grasshopper trestles were built and no drainage required, and there was no room to extend the slopes on account of the steepness of the banks, stone retaining walls were constructed and generally filled in behind with stone debris.

In many cases the sites of the trestles were changed and thrown into the banks, so as to take out curves and at the same time enable the filling to be made without building expensive retaining walls. This has been carefully studied and economically carried out, the line having

been thrown in just enough to furnish filling for the trestles, and thus material was obtained close at hand, and the quantity required was reduced by throwing the fills up the hillside and placing more of the track on solid ground.

PNEUMATIC DUMP CARS.

The material used in filling trestles on the Eastern and Western Divisions was loaded with steam shovels on flat cars, and unloaded by means of the ordinary ballast plow, drawn over the length of the train by the locomotive. On the Pacific Division a large portion of the work was done in the same manner. Where the filling was on side hill, a one-sided or side hill plow was used, and on straight track worked fairly well, but on sharp curves it caused a great deal of delay, and very materially increased the cost of the filling. In order to overcome this, all the various dump cars in use were examined in the latter part of 1891, and inquiries made from the principal manufacturers of cars and the leading Railway Companies and contractors in the United States, when it was found that there was not in use in any place a dump car that would answer the purpose, viz., one that could be unloaded without sending men along the track over the high trestles to do the work, which would have been slow and dangerous, and in order to avoid this, the question of operating dump cars by power, obtained from the locomotive, using either steam or compressed air, was then considered, when it was found that a plan for using compressed air had been patented in the United States, but had not been put into use. From this design as a basis, and after a number of important changes had been made on it in the Canadian Pacific Car Department, fifty cars were built in the Company's Car Shops in the Spring of 1892, and sent to the Pacific Division where they gave the most complete satisfaction; trains of twenty cars being regularly unloaded, and brought back into position ready to return to put in half a minute, which, of course, very materially reduced the cost of the filling. This, it is believed, is the first instance where dump cars on Railway Works have been unloaded by means of compressed air.

HYDRAULIC FILLING.

Two large embankments, one containing 66,000 yds. and the other 144,000 yds., have been made by hydraulic gravel from adjoining hills. The first embankment was filled at a cost of \$5,839.51, of which amount \$2,862.43 was for labour, and the balance, \$2,977.08,

was for plant and material used in boxes, etc. The iron pipes, monitors and part of the material in the boxes can be used again, and in fact are now in use at the second embankment, so it was considered fair to charge only 20 par cent. of the plant against the cost of filling, which reduced the total cost to $4,715.33, or 7.15 cents per cubic yard.

The second embankment is now being successfully made. The water is taken from the stream, which runs down the valley that has to be filled, at a point about 584 feet up the hill side, and 353 ft. above grade, or at an elevation of 125 ft. above the pit from which the gravel is taken for filling the ravine. The water is carried in a 15 inch pipe to a giant or monitor, such as is used in hydraulic mining. This monitor is generally worked with a five-inch nozzle, and throws a powerful stream against the gravel bank, washing the gravel and boulders down into a flume which has a grade of from 11.5 feet to 25 feet per 100 feet. This stream will carry down on to the dump 750 cubic yds. in 10 hours. One man is required to work the monitor, another is at head of sluice, and two along sluice to start and keep moving boulders that can pass down the flume, but are liable to lodge on a flat side, and three men are required to direct the material as it comes from the flume and to put in brush at the outer edges, so as to prevent the water from cutting channels in the slopes. Old sleepers taken out of track have been used for this purpose most successfully, by simply placing them on the outer edges of the bank, and when the gravel is raised up to the top of them, a new row is laid down on the lines of the slopes, and so on, new lines of ties being put in for each six inch rise of the bank. There are a number of places on the line where this method of filling is to be adopted.

RETAINING WALLS.

Large numbers of retaining walls have been built along the Fraser and Thompson Rivers at grade to replace the grasshopper trestles, and long structures of crib wharfing put in by the Government. Some of these walls are 100 ft. in height, and have in all cases been built of concrete mixed with large stones, generally found at or near the site of the wall. This work has been done in the most economical manner possible, by intelligent labourers, specially instructed as to how such work should be built. When these walls were commenced, Portland cement cost on the Pacific Coast $5.50 per barrel of 400 lbs. It was therefore desirable to use as little of it as possible, and yet enough of it had to be used to cement the stones in the most thorough manner. Large angular stones, as they came from the quarry, or as they were

picked up along the track, were first laid down on their largest beds on the foundation; cement mortar, three of sand to one of cement, was then put into the bottom of the angular spaces, and into this mortar small angular stones taken from rock slides were mixed, and into this mixture larger angular stones were carefully rammed, the angular point downward, so that they nearly touched the first large stones laid; when the large spaces were filled and the course levelled off, grout was poured on to fill any vacant spaces and to more thoroughly cement the whole mass together. This method required less than one-half the cement used by ordinary masons in building rubble masonry, and as it was done by labourers, there was the large saving in the labour as well as in the cement, and the work is certainly very much better than the average rubble built by masons. When there was room to build retaining walls at the bottom of the slopes, and when they could be built with a batter of as much as 1 to 4, dry masonry was used.

WATERWAYS—STONE.

At most of the fills it has been necessary to provide waterways in the form of bridges, stone arches, stone box culverts or cedar box culverts, the exception being where tunnels were made in rock points at one side of the fill. This has been found economical, and has been carried out wherever possible, the cost of a tunnel six feet by eight feet being about $9.00 per lineal foot.

Where the line is carried on side hill ground, over a deep valley, with a stream at the bottom, the stream, instead of being allowed to follow its natural course down the valley, and to pass under a bank requiring a culvert, say 200 ft. in length; has been tapped at an elevation a little above the rail level, and the water carried along the side of the valley in a ditch and over the bank, just under the rails. In many cases this method has proved very satisfactory, and of course economical, a culvert 20 feet long, of light construction, on a good foundation, taking the place of one 200 feet in length, of heavy construction and probably on a soft foundation.

Where waterways under heavy banks have had to be provided, and where covers were easily obtained, three feet by four feet box culverts have been built, with masonry constructed as already described for retaining walls, great care being taken to use the best cement and to fill all spaces between the stones. Where a three feet by four feet box culvert was not quite large enough to carry the water, or where covers were not easily obtained, small arches have been used, the arch ring

being built of rubble laid in cement. These arches in most cases have cost less than box culverts, as the stone for the entire arch, except coping and outer ring of arch, was generally found either on the site or at the end of an adjoining rock cut, whereas the covers for the box culverts would have had to be specially quarried, and often hauled long distances, which very materially increased the cost of the culvert, and where this was the case, arches were always adopted.

In places where a waterway of from 20 feet to 30 feet in width was required, arches have been adopted in preference to short iron spans of any kind, when the cost was not much in excess of the spans. Arches have always been found to be cheaper, where provision was made for double track. Semi-circular arches have been found to be much more expensive than flat arches, as the wings to catch the slopes for flat arches are very much smaller, and as the width of water-way is what is wanted in most cases, many flat arches have been built. For a 14 feet arch under a 46 feet bank for instance, the quantities are as follows: for single track flat arch 639 yards, and semi-circular arch 805 cubic yards, for double track flat arch 697 cubic yards, semi-circular arch 897 cubic yards, the distance from bottom of stream to springing being the same in both cases, as also the depth of foundation. Semi-circular arches on high walls have been used under the heavy fills in the deep valleys that run into the Fraser, as the streams in these valleys at times carry down timber debris, which is liable to jam at the entrance of the culvert; and as the streams have rapid falls, a culvert might soon be flooded up to its top, and for this reason culverts are built with high waterways, wherever it is considered safe to put in an arch. Great care is required in fixing the dimensions of water ways in the mountains, for even after years of study of a stream, and when it is thought that it has been seen under all conditions of flood, something happens to upset all former experience and conclusions. A slide often takes place up in the mountains, which may turn two streams into one, and send down with that one a large amount of timber debris, which formerly, but to a lesser extent, came down some other stream, and afterwards the small stream becomes the larger one, and *vice versa.*

CEDAR CULVERTS.

There are many places on the line where stone structures for water-ways would have been expensive on account of the great distance which the stone would have to be hauled, and in other places, foundations for stone structures would have been very expensive, and it be-

came necessary to substitute something else. Iron pipes were expensive, and required a very long haul. Earthenware pipes were cheaper, but also required the long haul, and in some cases were found to be affected by the frost. Wooden culverts built of cedar timber, of which we found large quantities along the line, seemed to meet the requirements: 1°, the timber is cheap; 2°, there was in all cases a very much shorter haul than that required for stone, iron or earthenware; 3°, it required a much less solid or uniform foundation; a settlement of a few inches more at one point than another did it no harm, and cracks that would have seriously injured stone, iron or earthenware from such a settlement did not arise in cedar timber, its elasticity permitting considerable settlement without any injury to the structure. As to its permanency, there is no question but that cedar will last at least fifty years, quite as long as much of the stone that is found on many railways. There is a cedar fence on the Aylmer Road, between Ottawa and Aylmer, that in 1876 was fifty years old, which was then being taken down to straighten it up, the owner of which said that he would take off the bark and rebuild the fence, when he considered it would be good for another fifty years.

A cedar log is to be seen in the Stanley Park at Vancouver, British Columbia, in a good state of preservation, on which a tree of 10 feet 6 inches in circumference has grown with one fork of the roots on one side of the tree and one fork on the other side. Similar trees to the one growing on the cedar in the same place have 168 rings, showing them to be 168 years old. There is a hollow cedar log in the same Park 4 feet 6 inches in diameter, the shell being six inches thick, which is quite sound. Over this log is growing a spruce tree, which measures 13 feet 6 inches in circumference at 8 feet above the log, and at 14 feet above the log it is 12 feet in circumference, which is 192 years old. From this evidence of the lasting quality of cedar in different situations, it is fair to assume that cedar culverts will last at least 50 years, and that they may be considered permanent work; for the saving in interest on the extra cost of iron or stone will renew these structures if necessary much sooner than at the end of fifty years. Cedar culverts have been put in where the banks are twenty feet and under and where bad foundations or excessive haul rendered the use of stone, iron or earthenware too expensive in comparison with cedar at the point in question. These culverts, generally three feet by three feet inside measurement, are made of 10 inches by 10 inches square timber, and in some cases double or treble, side by side. The timbers are securely treenailed

and bolted, and upright timbers are fastened to the outside at intervals of about four feet, so as to prevent the water from following along the outside of the walls, and so endangering the structure. See Plan No. IV.

BRIDGES.

The great number of long high trestles requiring waterways from 80 feet to 100 feet in width, with the rail 80 feet to 100 feet above bed of stream, led to the adoption of the following structure, which is considered to be that which most satisfactorily fills the requirements of the case: three spans of one hundred feet, with two piers, and the ends of the outer spans standing on cedar cribs founded on piles. By this plan we get a good, safe, substantial structure at a present cost of the piles and cedar cribs, against the two short stone abutments, effecting a saving of $14,000 for 80 feet height. By the time the cribs and piles require renewing, the bank will have settled, so that masonry can be built upon it instead of through it; and leaving the question of interest aside, there is a saving of 1200 yards of masonry, or $13,500 at each bridge, and the structure is equally as good for all practical purposes, and will require no more looking after than if it had all been built in stone, as an inspection is made of all structures at least once every month. See SkowWash River, Plate IV.

In rebuilding structures over that portion of the Eastern Division lying between Carleton Junction and Sudbury, a distance of 295 miles, and on the Western Division between Fort William and Winnipeg, a distance of 428 miles, masonry has been built for double track, and of course this consideration materially changes the character of the structures that have been adopted. Stone arches have been more frequently used here than on the single track sections, on account of their economy over small truss spans. On single track, where the cost of truss and arch was nearly the same, on double track, the arch would be very much cheaper, as the difference between a 25 feet arch, single and double track, say in 30 feet bank, is only 16 per cent., whereas for the same span of iron on masonry abutments the excess is never less than 45 per cent. For a 25 feet arch in 20 feet bank, the difference between single and double track is only 32 per cent., whereas for the most economical girder the excess of double track over single is never less than 80 per cent. The arch requiring only 13 feet of additional length of barrel, or centre portion of the arch, whereas the truss requires an additional span and 47 per cent. more masonry. This is, however, offset by the fact that the expenditure for the arch must be made at once, whereas

the truss and some of the additional masonry required for it may be postponed till actually required, but the economy of the arch is so great that it has been put in wherever possible.

An important part of the reconstruction has been the replacing of wooden bridges with structures of stone and steel. Wooden bridges have been carried over as long as they could be rendered absolutely safe. In most cases where a bridge showed the slightest sign of weakness, or when it was thought from its age that it might be becoming weak, it was strengthened by putting pile bents under the second panel point from the end, thus reducing a hundred-foot span to one of 60 feet, and of course strengthening it in like proportion. The structure was then carefully watched, and renewals commenced, so as to have the new bridge in before the old one was worn out.

In renewing the work on the old sections of the line, as, for instance, between Quebec and Montreal, it was found that considerable economy could be effected by the use of short spans, without at all interfering with the waterway or with the passage of ice, timber, etc.

The Jacques Cartier bridge, as originally built by the Quebec Government, had one 170 feet span and one 140 feet span on masonry abutments and pier. To rebuild these spans in steel would have cost $25,629. By adopting two 85 feet spans and two of 74 feet the cost was only $21,105.39. This of course included additional masonry piers, and also the diversion of a mill-race, which was under one of the spans, where it was required to build the pier. The short plate girder spans require much less care and inspection than the longer spans, and are much cheaper to maintain. See Plan No. I.

At Port Neuf the old bridge was built with one 80 feet span over the stream and two side spans of 150 feet. One of these large spans was adopted on account of the bad character of the foundation, but it was found economical to put in two 75 feet spans in the place of each of the 150 feet spans, and to carry the bad foundation down to the hard bottom, and drain the surrounding ground, as the renewal of the original spans would have cost $25,600.98, and the work was done for $22,169.-37, and a better structure obtained. See Plan I.

At Arnprior, which is on the section built by the old Canada Central Railway, and as mentioned above—being between Carleton Junction and Sudbury — has all new structures built for double track, two old combination trusses of 150 feet required renewing. The centre pier on wooden crib was in 39 feet of water, and was continually settling, so that a new pier was required. It was found that to build a new pier

for double track and single track spans, the cost would be $36,149.15, for the bridge complete with double track spans $60,978.95, and that by putting in two new double track piers and three 100 feet spans for single track, the cost would be only $32,093.61, and with the bridge complete for double track $45,687.20. The abutments were built in the early days of Railways, when economy was not very much considered; they were 21 feet wide between the parapet walls, which were four feet thick, so that by removing these walls back to the ballast wall, we obtained an abutment 29 feet in width, wide enough for a double track bridge.

The piers of this bridge were put in by sinking bottomless caissons through the water and the mud, which overlaid the rock to a depth of 39 feet. This mud, which was three feet thick, was removed by divers, and concrete to a depth of 20 feet was deposited inside the caisson through the water. When the concrete was all in, the water was pumped out and masonry built on top of it. Each pier contained 257 yards of masonry, and cost $2,661.50, or $9.50 per cubic yard. The excavation in the caissons under water cost $372, or $6 per yard. See Plan No. I.

The Gull River bridge on the double track section between Fort William and Winnipeg, as built originally in 1880 by the Government, was composed of one span of 100 feet, two spans of 80 feet, and eighty-five feet of trestle. The cost of replacing these three spans in 1891 in masonry and steel, that is, with masonry complete for double track, and steel for single track, would have been $41,600, and complete for double track, $55,800; but by using one span of 130 feet with stone arch abutments of thirty feet span, the cost was $33,166, and to complete for double track the cost will be $41,260. The base of rail on this bridge is 23 feet above low water. The bed of the river is composed of fine sand, and the masonry was founded on piles, capped with timber below lowest water. See Plan I.

The Stony Creek bridge on the Pacific Division, near the summit of the Selkirks, built in 1885 over a chasm 300 feet deep, has been replaced by a steel arch of 336 feet span. The wooden structure was composed of continuous Howe trusses of 33 feet, 161 feet, 172 feet, and 86 feet, supported on wooden trestle towers, and would have been serviceable for some time longer, as the timber, which was Douglas fir, was in good condition; but the Management, in view of the difficulty of replacing such a structure in case of its being burnt, and of transferring the traffic over such a chasm, decided to rebuild it in steel in

1893, and fortunately this was done before the fire of 1894, which swept over the western end of this structure and under it, destroying everything in its way that would burn. The walls of this ravine consist of decomposed mica schist, broken by numerous veins of quartz, upon which a good foundation could not be obtained or made. It was therefore decided to put in a span of 336 feet in the shape of a three-hinged arch, with one span of 60 feet at the west end and one span of 80 feet at the east end, and to build this arch outside of the old structure, it being impossible to improve the crossing by any change of location. Very inexpensive foundations were required with this arrangement, and by placing the trusses of the arch outside of the girder, and carefully fitting the floor beams to the old spans, it was possible to place the arch in position without cutting out rods or braces to such an extent as to weaken the old trusses or interfere with the traffic. The arch was erected on a light false work, and by using six inch pins at the connections with 12 inch covers or thimbles, on which the chords bore, as shown on Plan No. III, the connections were made very readily, no field riveting being required at the connections, except on the lateral bracing which covers the joints at top and bottom. The estimate based upon the Company's Standard Specifications for a 380 feet span and one span of 80 feet was $82,824, and for a 336 feet arch, one 80 feet and one 60 feet girder, $77,360. As this bridge is on a grade of 2.08 per 100 with a curve on the western end of the span, the standard load was increased by 25 per cent., which brought the cost of the structure to $96,075.67, of which $74,032.88 is for steel and the balance for masonry, retaining walls and floor.

The Salmon River bridge, put in by the Government, over the mouth of a rapid stream on the Fraser River, 137 miles east of Vancouver, was composed of one 200 feet span double intersection truss and two spans of 80 feet. The double intersection truss gave out before the road came into the hands of the Company, and was supported by braces and straining beams. This class of truss, designed with a minimum of iron and a maximum of wood in the web members, on account of the great cost of iron on the Pacific Coast, did not prove satisfactory, and required strengthening or supporting in nearly every case before the Company could run heavy engines over it. With similar spans these trusses have only about one-half as much iron in the web members as an ordinary Howe truss; in this truss the proportion was as 9 to 16. The river at the point of crossing is very rapid, and false works would have been difficult to erect and maintain, so it was decided to put up a hinged arch of 270 feet span and three spans of 50 feet, estimated to

cost $44,413. To rebuild the structure with one span of 160 feet, one 80 feet, one 70 feet and one 60 feet, the cost was estimated at $55,-807. When excavating for the foundation of the west abutment in mica schist, similar to that at Stony Creek, an extensive slide took place, which necessitated greatly increasing the quantity of masonry and lengthening the gap to be covered, so that the bridge, as built 34 feet south of the old structure, is made up of one 270 feet hinged arch and four 50 feet plate girders, the cost of which was $57,966. The arch was erected as a cantilever, as shown on Plan No. II.

In giving this very general idea of the character of the work done, and in showing to some slight extent the economy that has followed the use of temporary work in the original construction, I have trespassed longer upon your patience than I intended. Much that would be very instructive has had to be passed over entirely, and none of the work has been more than touched upon.

In conclusion, I would like to impress upon our younger members the necessity that exists in this new Country for the practice of economy in all the works they happen to be engaged upon.

We have a great work to do in building up a Country which stretches from the Atlantic to the Pacific, filled as it is with great natural resources of all kinds awaiting development, and but little money to do it with; and if we can so carry out our works that they are good and substantial, and at the same time cheaply constructed, so that the Capitalists who furnish the money can get a fair return for its use, we may expect more money from them, and other works will be carried out that will give employment to Engineers and prosperity to our Country. It is quite an easy matter to build an expensive structure, but it is an Engineer's duty to build an effective structure for the least possible cost, and after his design is made perfect as to its stability, he should proceed to remove from it everything that is not absolutely necessary and that has no duty to perform, remembering that he must never build ornaments, but that good and wise construction will be ornamental in itself.

Finally, you must also remember that your success in life depends on your capacity and willingness to take infinite pains with everything you are called upon to carry out. You must be in downright earnest about your work, and, above all things, you must be absolutely and entirely honest in every respect, never letting your convictions or opinions be warped in any way for any consideration, and then, if you may not always command success, you will at least deserve it, which is often better.

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